The Experiences and Perceptions of New Zealand Mathematics Teachers at Form 6/7 with regard to the Use of Graphics Calculator in Secondary Mathematics Education

Dissertation Submitted in Partial Fulfilment of M.Sci. Ed.

University of Canterbury

Fong Chih John Chang

January 2000

Chapter 1

Introduction

Graphics calculators: an Aid and a Partner

In the plenary presentations of 'TG 18: Roles of calculators in the classroom' at ICME 8, Jones (1996) claimed that graphics calculators had a great potential to enhance the teaching and learning of mathematics in secondary schools. He advised that we should be careful not to view them as just sophisticated labour and time saving tools for, if we did, we would not fully achieve the potential of this technology. We should treat a graphics calculator as an aid to learning and understanding mathematics a well as a partner in mathematical activity.

Effects of Graphics Calculator Use in High School Mathematics

Possibilities and effects of using graphics calculators were discussed in this forum. Graphics calculators were generally recognized, by professional scholars in this forum and by many recent researchers (Fox 1998, Hollard & Norwood, 1999; Abuloum 1996, Tharp, Fitzimmons & Ayers 1997), as a powerful and influential tool in secondary or first year undergraduate mathematics education. Besides, studies of Bradley & Kissane (1996), Geiger (1997) and Simmert (1997) showed that graphics calculators could have significant influence in certain parts of mathematics curriculum.

Influence of graphics calculators use upon assessment and evaluation and possible applications of this technology have been shown in the studies of McCrae (1996), Penglase & Arnold (1996) and Tobin (1997).

There is no doubt that the graphics calculator is not fully used by all secondary students over the world. For instance, in the United States, where the National Council of Teachers of Mathematics (NCTM)'s Curriculum and Evaluation Standards assumed the availability of graphics calculators to all students from the 9th grade onwards as early as 1989, Milou (1998) showed that in some areas only 36% of the schools could provide graphing calculators for students. In Australia, a class set of graphics calculators could be available to students only in certain affluent regions like West Australia or Victoria. In Hong Kong, teachers and students rarely use graphics calculators which are not allowed in public examinations like the School Certificate Examination and Advanced Level Examination.

Factors Affecting the Use of Graphics Calculators in Mathematics Class

Accessibility.

Kissane (1995) pointed out that there had been a steady increase in interest in graphics calculators by students, teachers, curriculum developers and examination authorities. The study showed that more people have recognized that *accessibility* of technology at the level of the individual student was the key factor in responding to technological change and the experience of the last decade. This recognition suggested vigorously that mathematics teachers were well advised to pay more attention to graphics calculators than to microcomputers. As evidence of this trend in the United States, Kissane cited the issue (April 1995) of The Mathematics Teachers, the NCTM journal focused on high school mathematics. The evidence was strong: of almost 20 full pages devoted to paid advertising, nine featured graphics calculators, while only two featured computer products, with two more featuring both computers and graphics calculators.

Although microcomputers have some significant advantages over graphics calculators for secondary mathematics education, such as being more powerful, faster, having larger and usually colorful screens, their high costs and bulky sizes prevent most students from using them in class frequently. All the advantages would be in vain if students could not access and use the technology frequently. When considering accessibility, a graphics calculator can easily beat a microcomputer by its comparatively cheaper price and its easy portable size.

But, on the other hand, although the price of a graphics calculator has gone down significantly in recent years, it is still relative expensive as compared with paper and pencil, chalk, textbook, a scientific calculator and other bare necessities of mathematics education. The cost of graphics calculators has been identified by educational researchers (Donald 1998, Milou 1998, Kissane 1995,) as the main barrier to a widespread of using them in high schools. The *accessibility* of graphics calculators by senior form mathematics teachers and students was the first area this study would like to explore.

Teacher's experience, beliefs and training in using graphics calculators.

Another important factor that affects the use of graphics calculators in secondary mathematics education comes from school teachers. Kissane (1995a,) has pointed out that

> *However, it needs to be acknowledged that the role of the classroom teacher is central, but easily overlooked in importance.....secondary mathematics teachers are unlikely to embrace and successfully integrate graphics calculators (or indeed any other forms of technology) into their teaching without considerable help.* (pp. 6-7)

The school-centred policy in New Zealand allows each high school the right of using or rejecting a technology such as graphics calculators and mathematics teachers usually play a key role in making this decision for their schools.

Fleener (1995) pointed out that teachers might respond differently to calculator experiences because of some combination of prior experience and philosophical orientation. Broman (1996) claimed that neither teachers nor textbooks seemed to have realized graphics calculator's advantages for the teaching and learning mathematics. Studies of Abuloum (1996) and Myers (1998) showed that there was a significant relationship between the use of graphics calculators and teachers' perception, attitude and level of training. Donald (1998) showed that unless using graphics calculators is compulsory, some mathematics teachers would not use graphics calculators in their classrooms. His study also showed that without the financial support from local government, sufficient number of graphics calculators for all students could not be guaranteed. Teachers' experiences and beliefs of using graphics calculators; their training and outside support in this technology were the second and third areas of interests of this study.

Curriculum and Assessment.

Bradley, Kissane & Kemp (1996) and Stacey (1996) showed that the mathematics curriculum was another factor that mutually affected the use of graphics calculators in class. Just as the graphics calculator has the potential to influence the curriculum (Bradley & Kissane, 1996; Geiger, 1997; and Simmert, 1997), so the curriculum itself can influence people to use or not to use graphics calculators.

In New Zealand, the official curriculum Mathematics in the NZ Curriculum (1992) states:

> *Graphics calculators are learning tools which students can use to discover and reinforce new ideas. They enable students to concentrate on mathematical ideas rather than on routine mechanical manipulations, which often intrude on the real point of particular learning situations.* (p.14)

The official NZ curriculum seems to encourage the use of graphics calculators in secondary mathematics. Yet it is possible that this encouragement is nullified by the structure of the assessment. Effects between graphics calculators and assessment has been shown in studies of Kemp, Kissane & Bradley (1996), Oldknow (1997) and

Mitchell (1997). There were two themes in the fourth area of this study: which part of the curriculum was a graphics calculator most helpful and whether there was any effect of a public examination upon the use of graphics calculators in high school mathematics education.

Research question

What are the experiences and perceptions of mathematics teachers at Form 6/7 in regards to the use of graphics calculator in secondary mathematics education?

In order to get a clear picture of the use of graphics calculators in senior mathematics classes at high schools in New Zealand, this study investigated the experiences and perceptions of mathematics teachers at Form 6/7 in regards to the use of graphics calculators in secondary mathematics education. It focused on the four main interwoven areas mentioned above, seeking answers to the following questions:

Accessibility of graphics calculators in high schools.

1. How many teachers had their own graphics calculators?
2. How many teachers used graphics calculators in class and how frequently did they use them?
3. How many students had their own graphics calculators?

4. How many students used graphics calculators in class and how frequently did they use in class?

Teachers' experience and beliefs.

1. What were teachers' concepts of teaching and learning mathematics?
2. Why did some teachers not use any graphics calculators in their mathematics class?
3. Did the using of graphics calculators affect their students' learning mathematics? How if it did?
4. What were the main advantages and disadvantages of using graphics calculators in secondary mathematics education?

Training and support.

1. How many teachers had been trained in using graphics calculators and how were they trained?
2. How many teachers had confidence in using graphics calculators?
3. What kind of support did they get or would they like to get?

Graphics calculators, mathematics curriculum and assessment.

1. In which areas of the curriculum was a graphics calculator most useful?
2. Would the using of graphics calculator in public examination affect teachers' strategy in using graphics calculator in class?

Chapter Two

Literature Review

Nature of a graphics calculator

In addition to all the facilities of a scientific calculator, the 'first generation' of graphics calculators provided data analysis, linear algebra, programming and, as the name implies, the graphing of functions. This graphing component has been the most frequently used facility of a graphics calculator within secondary mathematics courses. Using it, a student has been able to represent Cartesian, polar and parametric functions or equations graphically on a small screen and inspect visually a graph's properties by 'zooming in' or 'zooming out' to suitable regions.

New capabilities such like numerical approximation options for equation solving, derivatives and definite integral were added to the so-called "second generation" graphics calculators. Nearly all the functionality of advanced mathematical software for desktop computers can now be found in so called 'hand-held computers', the third generation graphics calculators.

A major consequence of these kinds of capabilities is that a graphical calculator can be used to *analyze* a mathematical situation rather than merely to perform a computation and this makes it much superior to a scientific one.

Some material written for the purpose of explaining the facilities which set it apart from the scientific calculators and giving examples of ways these facilities could be used include:

Cartesian & polar graphing (Clark & Leary 1994, Clarke & Clarke 1991, Leary 1991); Data entry and analysis (Cowling & Llewelyn 1994, Jones 1993, 1994; Sullivan 1990); Linear programming and matrix calculation (Tobbin 1991, Weal 1992); General programming (Humble 1992); Equation solving (Day 1993, Walton & Wines 1994); Numerical integration (Kissane 1993); Teaching 'line of best fit' (Rubenstein 1992); Algebraic Variables (Graham & Thomas 1997) Educational Statistics Courses. (Cage & Sharon 1996) Magic Number (Dowsey & Tynan 1997, Ravenscroft 1998) Exploring polynomials (Ruthven 1989) Sampling (Graham, 1996) Micromaths: Tea Cups, T Cubed, Discharge and the Elimination of Drips (Olknow, 1996)

Role of the Graphics Calculator in the Teaching and learning of various Mathematical Concepts

The appearance of graphics calculators provided a new teaching and learning paradigm: Graphs can now be used to study mathematics. Waits & Demana (1995) made the following comment in their *article "TI-92, the hand-held revolution in computer enhanced maths teaching and learning*":

> *Inexpensive graphing calculators fulfilled our dream of making computer visualization for both in-class and out-of-class activities practical for all students. Expensive computers and software located in expensive to operate (and maintain) computer labs were no longer barriers to regular student use*

> *of computer visualization and numerical methods in their mathematical education.* [p.2]

The work of Demana and Waits from the University of Ohio in publicizing the potential of these tools for high school (and college) teaching and learning had been a significant feature of this field internationally since the earliest days of the use of these devices (Demana & Waits 1992, Waits & Demana, 1988, 1989a, 1989b, 1992, 1995). A graphics calculator was believed to be a tool which opened up new ways to approach many problems and encouraged students to experiment and investigate (Arnold 1995?, Groves 1991, Kissane 1995, Leary & Clarke 1993, Piston 1992, Tynan et al. 1995). It allowed a shift in emphasis from algebraic manipulation and proof to graphical investigation (Day 1993, Demana & Waits 1992). Through its use, they had been able to extend the range of students' activities and problem solving components of mathematics courses (Clark & Clark 1991, Tobin, 1991). It enabled students to investigate various mathematics concepts & topics not previously accessible to them due to computational difficulty (Greenes & Rigol, 1992). The graphics calculator was thought by some to have significant advantages, such as cheaper price, small size and portable, over the computer as a tool in learning mathematics (Hackett & Kissane 1993, Jones 1991, Kissane 1995, Leary 1991).

Factors Affecting the Use of Graphics Calculator in Mathematics Class

Accessibility.

Research on graphics calculator use in secondary school mathematics is rather limited. Research on the accessibility of graphics calculator or teachers' perception to graphics calculator use in secondary school mathematics is even less. However, these do not mean that it is not important.

Ruthven's study (1990) not only confirmed the influence of graphics calculator on both the mathematical attainment of students and the mathematical approaches that they employ, but also revealed the importance of such calculators being accessible in order to have our students benefit from this technology. This can clearly be seen from the last sentence of his conclusion:

> *Moreover, it suggested that this influence may depend as much on the way in which information technology is used to mediate mathematics in the classroom as on simple access to the technology.* (p.449)

Kissane (1995b) shows there is a growing recognition that accessibility of graphics calculator at the level of individual student is an important and appropriate strategy in secondary mathematics education. The individual access to graphics calculator for our students is critical for their future success in this fast changing technological society. Penglase & Arnold (1996) commented:

Adoption and use of graphical calculators within high school and tertiary institutions in developed countries appears increasingly widespread. In Australia, recent legislation permitting their use in high stake external examinations in Victoria and Western Australia serves a precursor for widespread adoption (in the senior school, at least), which other states seem likely to follow." [p.60]

From emails among some scholars or teachers in mathematics education in Australia and New Zealand during the time 15 September 1998 to 12 November, it was noticed that rates of using graphics calculators for final high school students in 1998 were respectively 100% and over 90% in Victoria and WA, Australia. In one email, the writer wrote:

I recently (as in the last two days) spoke to a head of department of a school on the north coast (of Queensland) *whose clientele consists of about 70% single parent families and whose social-economic circumstances are not as fortunate as those of us taking part in this conference. He has use GC* (graphics calculators) *technology with his students for the past five years, has lost one, and has had one of well over a hundred slightly damaged.* [i]

The following was showed in another email:

My school is the only government provider for Year 11 and 12 students so they all come to us. We have worked from class sets TI82s then TI83s to this year full ownership for ALL maths students.

The response from students particularly in our low level maths classes, 17 classes of 25 students, (some barely numerate!) has been very positive.[ii]

As a reply to Stephen Arnold, Alan Cadby of Hale School, WA confirmed, in his email to AAMT@listserver.eddirect.com on 5th Nov 1998, that all his students in Year 12 who were to complete a tertiary maths course were expected to have each a graphics calculator which to be used in the Tertiary Examination and he would have been if most of the Year 11's did not have their own graphics calculators.

According to David Leigh-Lancaster, a survey by the School of Mathematical Sciences at Swinburne University of Technology showed that, in 1998, only 7.8% of students did not have ready access to a graphics calculator.[iii]

Public exam has a significant influence to students' accessing graphics calculators. Its influence is detailed in the last section of this chapter. [p.2]

It was clear that the commercial market, especially in the United States, had been well aware of this trend several years ago. It was reported in 1995 that the US sales of graphics calculators was around six million units per year, and rising. There are four major manufacturers of graphics calculator, all making their products aim directly at the high school market to meet the educational needs of students and their teachers.

On the other hand, there are some factors that affect the accessibility of graphics calculators in high school. Two main factors identified by research (Broman, 1996; Milou, 1998; Kissane, 1995a,b; Kissane, Bradley & Kemp, 1994; Abuloum 1996; Simmt, 1997; Tharp, Fitzsimmons & Ayers, 1997) are: (1) cost and (2) teacher's experience, beliefs and training in using graphics calculators. Milou (1998) and Kissane, (1995b) pointed out that *cost* was a major factor in the non-use of graphics calculators. Abuloum (1996) showed that the use of graphics calculators in the classroom was found to have a significant relationship with teacher's level of training and many teachers who used graphics calculators in teaching algebra had not been adequately trained. Simmt (1997)'s study showed that some teachers strongly favoured 'traditional' approach' that

> *Although the use of graphic solutions to max/min word problems was mandated by the government, the teachers simply did not use them.* [p.287]

Kissane, Bradley and Kemp (1994) pointed out inequitable access to graphics calculators among a class of students, and inequities arising from differences between the capabilities of particular graphics calculators would create problems in equity and discussed various methods tackling this problem.

Teachers' perceptions and attitudes towards graphics calculator use in classroom.

Fleener (1995) analyzed the responses of 94 secondary school teachers about graphics calculator use and reported that teachers surveyed had a similar view of the effective potential of calculus use and her study pointed to the relationship between core beliefs and experience related to graphics calculator use. Teachers could respond differently to calculator experiences due to some combinations of prior experience and philosophical orientation. For example, teachers who felt "students should not be allowed to use calculators until the students have mastered the concept or procedure" (item 9- Mastery = yes) generally agreed (53%) that "calculator use would cause a decline in basic arithmetic facts" (item 2). But for those who held opposite feeling (item 9- Mastery = no), 79% disagreed with the conclusion (item 2). Teachers who formed the "Mastery = Yes" group were split in their responses to the statement: "Students understand math better if they solve problems using paper and pencil"(item 8). Only a slightly majority (52%) of the Mastery = Yes group disagreed with item 8 while a large majority of the Mastery = No group (85%) disagreed.[p.491]

According to Simonsen & Dick's (1997), their study showed that the teachers' perceptions of the advantages of graphics calculators appeared to be instructionally related, (67% for "less distraction with computational detail"; 63% for "availability of immediate feedback; 56% for "enhancement of visualization" and 30% for "development for connection". p.248) whereas the perceptions of the disadvantages appeared to be primarily logistical in nature (59% for "logistical differences and lack of access"; 52% for "problem with security; 41% for "time spent learning calculator"; and 37% for "fear of calculator-dependency" p.251). There was considerable reluctance to deviate from stringent curriculum requirements that are reinforced by standardized tests (78% for "increase preparation time'; 59% for "increase mathematical depth'; 26% for "necessity of technological exposure" and 22% for "influence of the advanced placement (AP) examination. p.257)

The graphics calculators were thought by some (Hackett & Kissane,1993; Jones, 1991; Kissane, 1995b; Leary 1991) to have significant advantages over the computer as a tool in the learning of mathematics. But Myers' (1998) findings suggested a lack of decisiveness as to the role of graphics/symbolic calculators in high school mathematics and that teachers' beliefs influence the use of the technology.

Milou (1998) surveyed 243 secondary mathematics teachers concerning their use of, and attitudes towards graphics calculators. The study which got a 60% return rate showed that all senior high school teachers and 56% of the middle school teachers used graphics calculators in class, while only 36.2% of the schools provided graphics calculators for students. A majority (85.5%) of the responding teachers believed that graphics calculator was a motivational tool and could make students try harder. However, the cognitive benefits of graphics calculator use in algebra was still questioned by many teachers in the survey.

In order to have a clear picture of the role of graphics calculators in high school mathematics in New Zealand, at least one needs to know the accessibility of both teachers and students to this technology as well as teachers' experiences, beliefs and training in using graphics calculators at senior forms in this country.

<u>Teachers' training, confidence in using graphics calculators and public support.</u>

Findings of Abuloum (1996) showed that:

1. There was a positive correlation between certain teacher characteristics and the mathematics achievement of the students.
2. Teachers with a high level of training tended to have students with high achievement scores.

3. The use of graphing calculators in the classroom was found to have a significant relationship with teachers' level of training, perceptions, and attitudes. Calculator use appeared to make teachers more effective, which in turn made students learn more.
4. Many teachers who used graphing calculators in teaching algebra had not been adequately trained in their use and had to often resort to self-training.
5. Little organized teacher training in the field of calculators was reported by the respondent.

Kissane (1995b) also pointed out that the needs of classroom mathematics teachers, in using graphics calculators, should be carefully attended if our society wants to gain maximal educational benefits from this technology. Fleener (1995) suggested that, further investigation of the interplay between teachers' experiences and their philosophical orientations, was needed for any in-service training aiming to promote teachers' use of graphics calculators in class.

Due to the fast progress of electronic technology, versions of graphics calculators changes as quickly as computers. Teachers need help to consolidate and update regularly their knowledge about this dynamic technology. How a teacher is equipped through properly designed external supports, such as workshops, in-service training, will directly affect their confidence and intention to use and teaching results.

<u>Effect of using graphics calculator on mathematics curriculum and assessment.</u>

The potential of this technology for widespread use, made feasible by its portability and also, to some extent, its price (Groves 1990, Jones 1991, Kissane 1995), has major implication for the mathematics curriculum. Revision of mathematics curriculum was believed to be urgently required (Dick 1992) with different emphasis on a number of topics (Kissane 1993), and possibly re-ordering of complete topics (Burrill 1992). The work of Demana and Waits from the University of Ohio in publicizing the potential of these tools for high school (and college) teaching and learning had been a significant feature of this field internationally since the earliest days of the use of these devices (Demana & Waits 1992, Waits & Demana, 1988, 1989a, 1989b, 1992, 1995). Substantial positive information can also be found in Góme & Waits (eds.) (1996), and Pomerantz (1997)[iv] as well as a detail description is presented in the critical review Penglase and Arnold (1996).

Followed are some examples of material written for the purpose of explaining how a graphics calculator could be used in teaching or learning various mathematical concepts or topics. Barling (1991), Barnes (1995), Clark and Leary (1994), Gomez & Femandez (1997) discussed *applications to calculus* teaching at high school and college levels. Olknow & Taylor, (1998) demonstrated how a combination of graphics calculators, a laptop, a Calculator Based Ranger (CBR) and a Calculator Based Laboratory (CBL) and a OHP could work together allowing students to have hands-on *experience in downloading, uploading* or sharing data with their classmates while data or result could to shown to the whole class through the OHP. Borenson (1990), Day (1993) and Paasonen (1993) outlined ways that the graphics calculator could be used to teach various concepts concerning the relationship between *function* and *graphs*.

Barnes (1994), Brown (1994), Groves (1992) and Knold (1992) demonstrated *modeling activities* and *exploration* to real data using the graphics calculator. Barnes (1994) and Brown (1994) looked at the interesting ways of investigating properties of *parabolas*. Vonder & Embse (1992) illustrated how its multi-line facilitated *problem-solving*. These studies serve as a great insight to finding out which part of the New Zealand mathematics curriculum will graphics calculators be most helpful.

Public examinations have significant influences to the using of graphics calculators. In United States, "approved" graphics calculators were first allowed to use in AP-Calculus in 1993. From 1995, candidates have been "required" to use "approved" graphics calculators in AP-Calculus. (Jones and McCrae, 1996) According to calculator policy 1999-2000, all students attending AP calculus must use some approved graphics calculators because an approved graphics calculator is "mandatory" in part A of the AP-Calculus exam. In UK, graphics calculators have been allowed in A-Level mathematics since 1994. During 1995, both Victoria and West Australia have made the decision to allow students to use graphics calculators in the public examinations used for tertiary entrance. This decision has been effective from 1997 for Victorian students and from 1998 for students in WA. In New Zealand, graphics calculators have been allowed in the Busary Examination as an interim measure with one exception that the use of TI92 was banned in 1998.

The involvement of graphics calculators in these public examinations has logically *assumed* that all final year students would have accessed to some graphics calculators. However, this is seldom true for most countries. Hot debates on the issue of equity during the mid-1990s have promoted such ideas as "calculator-free questions" or "calculator-independent questions". On the other side, the wide-spread of using graphics calculators has also promoted "calculator-base questions", i.e. questions for which it is expected that the calculator would have been used. It would then be interested to know how a Year 13 class mathematics teacher could do for the best benefit of his/her students in New Zealand.

Chapter 3

METHOD

Survey

In this study, a survey of all Form 6 and Form 7 mathematics teachers in New Zealand was carried out on a voluntary basis. A questionnaire was prepared as the tool of survey. A set of two identical questionnaires was sent by mail to all of the 243 high schools in New Zealand during mid-April 1999.

Survey Population.

All Form 6 and Form 7 (year 12 and year 13) mathematics teachers in New Zealand from the population.

Procedures.

Following procedures were used in the survey process.

- After reading the relevant literature and consulting some high school mathematics teachers, a questionnaire was prepared between March and early April.
- When the questionnaire was ready, two identical forms were sent to each of the 243 high schools in New Zealand in mid-April.
- Answered questionnaires were expected to be returned from late April to early June. These were collected to form the sample of this survey.
- Spread sheet software was used to store and analyse the collected data.

Sample.

175 answered questionnaires were returned, either by mail or by fax, and data collected from them form the sample of the survey.

Questionnaire.

Being the most important tool of this study, the questionnaire was prepared and validated according to the following steps:

- Draft.

A preliminary questionnaire was written via brainstorming. After reviewing some related questionnaires in the literature, a first draft was prepared in late February. Fleener (1995, p.484-485)'s AIM-AT Survey questionnaire; Simonsen & Dick (1997, p.267)'s Interview Protocol with categories 'Background Information', "Calculator Use in the Classroom', 'Teacher Attitude' and "Classroom Dynamics'; Simmt (1997, p.277)'s Table 3 of 'Ways in which the Graphing Calculator Were Used' together with Tharp, Fitzsimmons & Ayers (1997, pp.574-575)'s 'VANT Outreach Attitude Questionnaire-part II' were consulted and compared when setting up the format and content of my questionnaire. Simonsen & Dick's 'Background Information' was transformed into the 'Statistics' in my questionnaire and Fleener's 'AIM-AT categories 'Cognitive', 'Experiential' and 'Affective' conducted my classification of the questions in the questionnaire.

- Informal check by other mathematics teachers.

The first draft was shown to three mathematics teachers and my two Supervisors. A revised version was then produced with some amendments based on their critical feedback. Open-end questions were added while multiple choice and Likert-scale questions were reduced in quantity to keep the questionnaire size within three pages. This is to ensure that the questionnaire would be attractive and not tedious to target teachers. As advised by two mathematics teachers, phrases 'year 12' and 'year 13' were used respectively instead of 'Form 6' and 'Form 7' in the item 'Teaching class', and the item 'Highest degree' were deleted to avoid embarrassing some teachers.

- Desk test and professional comments on the revised version.

The revised version was desk tested by one classmate who is also a mathematics teacher. It was also shown to my two Supervisors for their professional comments.

Two items 'Age' and 'Gender' were deleted and a new item 'Number of mathematics classes per week' were added in the final version. The item 'Age' was deleted because there was already a more related item 'Years of teaching mathematics' in the questionnaire. "Gender" was deleted due to the expert experience of my supervisor Dr. Liberty. My another supervisor Dr. Hannah suggested the additional item for the purpose of quantifying teachers' teaching mathematics more clearly.

- Face value.

The face value of the questionnaire was assured when the questionnaire was processed through the above steps.

- Content validity.

A total of 27 questions were designed to explore the four main themes of this study: (1) accessibility, (2) teachers' experience and perception, (3) effect of using graphics calculators on curriculum and assessment, and (4) training and support.

Two 'yes-or-no' and three multiple choice questions were asked for the study of 'accessibility' of New Zealand high school mathematics teachers and students to graphics calculators:

- Do you have your own graphics calculator(s)? yes/no. If yes, (i) what model? (ii) year of using
- Do you use graphics calculators now at school? If yes,
  (i) what Model? years of using: If no, why not?
- I use graphics calculators in my mathematics classes ______.
- ___ my students use graphics calculators in my mathematics class.
- ___ my students have their own graphics calculators.

In order to explore teachers' experience and perception concerning mathematics teaching/learning and use graphics calculators, 3 fill-in questions, 1 multiple choice question, 8 Likert-scale questions together with 2 open-end questions were asked. The three fill-in questions were:

- Years of teaching mathematics
- Teaching class:
- Number of mathematics class per week at (i) year 12 [ ] (ii) year 13 [ ]

The multiple choice question was :

- I believe that graphics calculators are _____ tools in teaching and learning mathematics.

The eight Likert-scale questions were :

- Learning mathematics is mostly memorizing a set of facts and rules.

- Learning mathematics means exploring problems to discover patterns and make generalizations.
- Using a graphics calculator to teach mathematics allows me to emphasize the experimental nature of the subject.
- Using a graphics calculator to teach mathematics does not enhance student learning or understanding of concepts.
- The use of graphics calculators encourages student learning.
- Using graphics calculators makes teachers more effective.
- Graphics calculators should only be used to check work.
- Students lack the ability to work with a calculator as complex as a graphics calculator.

The two open-end question under this theme were:

- What are the main advantages of a graphics calculator?
- What are the main disadvantages of a graphics calculator?

Some answers to the above 2 open-end questions might reveal the effect of graphics calculators on mathematics curriculum and assessment. To get more information in this area, 2 multiple questions, 1 Likert-scale question and 1 open-end questions were asked. The 2 multiple questions were:

- The impact of graphics calculators on mathematics curriculum is
- The impact of graphics calculators on mathematics assessment is

The Likert-scale question and the open-end questions were respectively listed below:

- My strategy for using graphics calculators in year 13 differs from that in year 12 due to the Bursary Exam.
- In which parts of the curriculum are graphics calculators most helpful?

One fill-in, two Likert-scale and one open-end questions were used to find out how teachers were trained using graphics calculators and any supports granted to teachers in this aspect. They were listed below accordingly:

- Have you ever been trained using graphics calculators? If yes, how?
  (i) short course
  (ii) demonstration
  (iii) conference workshop
  (iv) self-instruction
- I lack confidence and skill with graphics calculators.
- Teaching with a graphics calculator is a high priority in my department.
- What kind of assistance can mathematics teachers currently get in the use of graphics calculators? Is this enough?

As a summary, the 27 questions were grouped into 4 categories as shown in Table 3.1.

Table 3.1

Content Distribution

Category	Question number
Accessibility of graphics calculators.	
• Teachers' accessibility	5, 6, 7
• Students' accessibility, observed by teachers	8, 9
Teachers' experience and perception.	
• Teachers' experience & perception of mathematics learning & teaching	1, 2, 3, 13, 14,
• Teachers' experience & perception of using graphics calculator	10, 15, 18, 19, 20, 21, 22
Effect of using graphics calculators.	
• on curriculum	11, 24, 25, 26
• on assessment	12, 23, 25, 26
Training and support.	
• Teachers' training / confidence in using graphics calculator & public support	4, 16, 17, 27

Three questionnaires / protocol from Fleener (1995), Simonsen & Dick (1997) and Tharp, M. L., Fitzsimmons & Ayers (1997) were studied and compared to ensure a certain degree of content validity of the questionnaire. Relationship between the contents of the questionnaire and those used in the above three studies is shown in the following Table 3.2

Table 3.2

Relationship between Graphics Calculator questionnaire and 2 other questionnaires or 1 protocol

Graphics Calculator Questionnaire John Chang 1999 (N = 27)	VANT Outreach Attitude Questionnaire-Part II Tharp & others, 1997 (N= 16)	Attitude Instrument for Mathematics and Applied Technology (AIM-AT) Fleener, 1995 (N=23)	Interview Protocol Simonsen & Dick, 1997 (N= 15)
1.	-	-	BI4[b]
2.	-	-	BI6[c]
3.	-	-	-
4.	-	-	-
5.	-	-	CC1[c]
6.	-	20[c]	BI5[c]
7	-	20[c]	CC1[c]
8	9[d]	17[c]	CC2[c]
9	-	18[c]	CC2[c]
10.	-	15[d]	-
11.	-	-	-
12.	-	1[d]	-
13.	5[a], 6[c]	-	-
14	7[a]	-	-
15	3[a]	23[d]	CD2[d]
16	12[a]	21[0], 22[0]	CC1[d]
17	13[a],	10[c]	CC1[d]
18	4[a]	19[c]	CD2[d]
19	-	3[c], 4[c], 11[b]	CD2[d]
20	3[d]	-	CD1[d]
21	1[b]	12[b]	-
22	14[a]	8[0], 10[d]	-
23	-	-	CC3[d]
24	-	6[c]	CA2[d]
25	2[d]	7[c], 8[c], 15[c]	TA2[c]
26	15[d],	2[c], 5[c], 14[c], 16[c]	TA3[c]
27	11[c], 16[d], 8[0], 10[0]	-	-

[a]. exactly the same [b]. nearly the same [c]. similar or partially same meaning

d. some relation   0. opposite meaning

Data Analysis.

Spread sheet software Excel was used to record and analyse collected data.

- Nonparametric statistics

As the data are collected on a voluntary base, it is not a random sample, only nonparametric statistical methods will be used.

- Generalization.

Because the survey included the entire population and because there is a large response rate, it is possible to make some cautious generalizations about the population as a whole.

Chapter 4

Results

Response Rate

In this study, it is difficult to show the response rate by only a number. A letter, each containing two copies of the same questionnaire, was sent to each of the 243 high schools in New Zealand in mid-April 1999 and a total 175 questionnaires were returned. The two questionnaires for each school were originally intended to be filled in by one Form 6 and one Form 7 mathematics teacher. But among the 175 replies, 127 were from teachers teaching both Form 6 and Form 7; 29 and 17 respectively from those who were only teaching Form 7 or Form 6. Besides, two blank questionnaires from the same school were returned with a letter explaining that neither the mathematics department budget nor the students themselves could afford the use of graphics calculators and instead they were using computers for exploring and practicing graphical concepts.

It is hard to determine how many schools have replied. In fact, one school in Auckland replied with 12 questionnaires, another two schools, one from Waikato and the other from Ashburton, each returned 5 questionnaires. There are another ten schools which each returned exactly 2 questionnaires. The remaining 133 questionnaires were returned individually. A distribution of these data is shown below in Figure 4.1

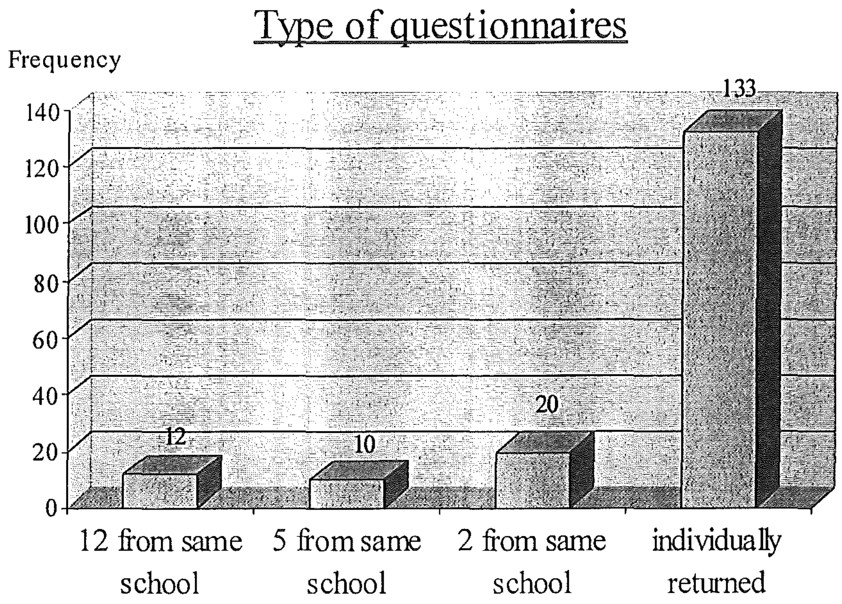

Figure 4.1

Geographical Origins

Among the 175 questionnaires collected, the geographical origins of 170 replies can be identified either by addresses supplied or by recognizable postal marks. There were 123 questionnaires from the North Island, 47 from the South Island. A distribution of the responding schools is shown in Figure 4.2.

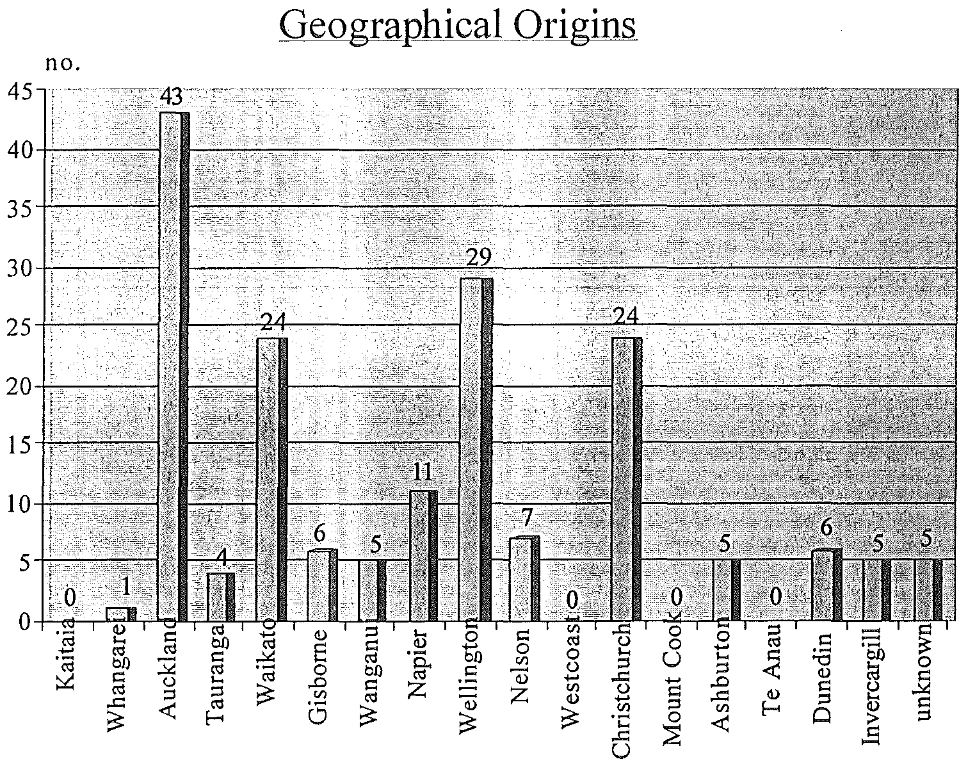

Figure 4.2

The key to maps of Road Atlas of New Zealand (AA 1993 p.4) is used to classify the geographical source of responding questionnaires. North Island is divided into nine regions and South Island eight regions. 43 replies come from region 3 where the most populated city Auckland is located; 29 replies come from region 9 where capital Wellington is located; 24 replies each from region 4 Waikato and region 12 Christchurch, the most populated city in South Island. This distribution of responses to some extent reflects the population distribution of this country.

Accessibility of graphics calculators

Five questions were asked in this field. Teachers' ownership and/or use of graphics calculator in school or class as well as their students' as observed by them were investigated.

Ownership of graphics calculator.

(a) teacher

Do you have your own graphics calculator(s)? *Yes* __ *No* __

If yes, (i) what Model? *[__]* *(ii) years of using:* *[__].* (Q_5)

Among the 172 teachers who commented on this question, 65 teachers said that they owned one or more graphics calculators and 107 said that they didn't. 63 teachers filled in the names of their graphic calculators and 54 teachers mentioned how long they had used them. One teacher owned 3 graphics calculators while another one owned 2. Data about the models used and years of using is shown below in Tables 4.1(A) and 4.1(B).

Table 4.1(A)

Personal Ownership of Graphic Calculators

Respondents Ownership of Graphic Calculators	Number of Respondents (N172)	
No = Do not own their own graphics calculator	107	
Yes = Do own their own graphics calculator	65 *	
Casio		50
Texas Instruments		11
Hewlett Packard		3
Sharp		2

* Only 63 respondents reported what graphics calculators they owned. There are two respondents who each owns two calculators while another one who owns three calculators.

Table 4.1(B)

Years Experience Using Own Graphic Calculators

Respondents Experience Using Own Graphic Calculator	Years Reported Grouped in 2 Year Intervals				
	0^+ - 2	2^+ - 4	4^+ - 6	6^+ - 8	8^+ - 10
Number Responding (N = 59)	33	18	4	2	2

So only a little more than one third of the teachers responding have their own graphics calculators. These numbers may have changed since the questionnaire, because one manufacturer was giving away free graphics calculators at the recent mathematics conference in Dunedin.

(b) student (observed by teacher)

___ *my students have their own graphics calculators. [ ]* **(Q_9)**

A. All of *B. Most of* *C. Some of* *D. None of*

171 teachers commented about their students' owning graphics calculators. The distribution of their responses is shown below in Table 4.2.

Table 4.2

Estimates of Student Ownership of Graphics Calculators

Students Ownership of Graphics Calculators	Ranking			
	All of my students	Most of my students	Some of my students	None of my students
Number Responding (N = 171)	0	1	73	97

From the above table, 43% of the teachers replied that only some of their students own their graphics calculators while more than half (57%) replied that none of their students had a graphics calculator.

Using graphics calculators in class.

(a) teacher

I use graphics calculators in my mathematics classes ___. [ ] **(Q_7)**

A. always B. sometimes C. when needed D. never

172 teachers commented on this question. About half (49%) of them said that they had never used graphics calculators and only one said that he/she has always used graphics calculators. The distribution of their answers is shown below in Tables 4.3(A).

Table 4.3(A)

Use of Graphics Calculators in Mathematics Class

Respondents Use of Graphics Calculators in Math Class	Ranking			
	Always	Sometimes	When needed	Never
Number Responding (N = 172)	1	34	53	84

(b) student (observed by teacher)

___ *my students use graphics calculators in my mathematics class.[ ]* (Q_8)

A. All of *B. Most of* *C. Some of* *D. None of*

172 teachers made comments on how their students used graphics calculators in class. The distribution is shown in the following Table 4.3(B).

Table 4.3(B)

Estimates of Student Use Graphics Calculators

Students Use Graphics Calculators	Ranking			
	All of my students	Most of my students	Some of my students	None of my students
Number Responding (N = 172)	17	9	66	80

From the above table, we can see only in 10% of senior classes do all the students have a graphics calculator while in just under half of the senior classes, no students have graphic calculators.

Teachers' using graphics calculators in school.

Do you use graphics calculators now at school? *Yes* __ *No* __ (Q_6)

If yes, (i) what Model? [__] *(ii) years of using:* [___].

If no, why not? ______________________________

- Using graphics calculators in school

81 teachers replied that they did use graphics calculators at school and of these 76 stated that they had experiences from 0.1 year to 8 years. These two number are both greater than 65, the number of teachers who had their own graphics calculators, so there were presumably some class sets being used. The distribution of these teachers' experience in using graphics calculators is shown below in Tables 4.4(A) and 4.4(B).

Table 4.4(A)

Respondents' Using Graphic Calculators in Schools

Graphics Calculators used by Respondents in Schools	Number of Respondents (N= 172)	
No = Do not use graphics calculators in school	94	
Yes = Do use graphics calculators in school*	81	
Casio		55
Texas Instruments		17
Hewlett Packard		1
Sharp		5

* Only 76 respondents reported what graphics calculators they used in school. There are two respondents each uses two different models.

Table 4.4(B)

Respondents' Years Experience Using Graphic Calculators in Schools

Respondents' Experience Using Graphics Calculators in Schools	Years Reported Grouped in 1 Year Intervals							
	0^+ - 1	1^+ - 2	2^+ - 3	3^+ - 4	4^+ - 5	5^+ - 6	6^+ - 7	7^+ - 8
Number Responding (N= 76)	30	20	15	5	3	1	1	1

- Not using graphics calculators in school

95 teachers said they did not use graphics calculators at school and 71 explained. Their number of reasons and explanations were classified in the following Tables 4.5(A) and 4.5(B).

Table 4.5(A)

Number of Reasons Given for Not Using Calculator

Respondents' Not Using Graphics Calculators	Number of Reasons Given				
	0 reasons	1 reason	2 reasons	3 reasons	4 reasons
Number of Respondents (N = 95)	24	35	27	8	1

Table 4.5(B)

Explanations for Not Using Graphic Calculators in Teaching

Reasons.	Number of Reasons. (N =71)
• Not available/ too expensive/ can't afford (school or students)/ cost/low priority	38
• Use or Prefer PC	21
• Not important/ can't find real benefit/ don't really help understanding/not necessary	11
• Lack of confidence / Lack of training	10
• Complex & hard to use/ Difficulty in distributing to students/ visual problems	4
• Others	6

For those who explained why they didn't use graphics calculators in school, over 50% had their difficulties in the availability of this technology due to a financial problem - they can't afford the cost; about 30% said they were using or preferred to use computers instead of graphics calculators; about 20% said either they didn't have enough confidence due to lacking training or finding it difficult to use this technology; about 15% said that neither they found it much benefit nor necessary using graphics calculators in school. Example statements are shown below:

'Not available. More likely to have access to PCs.'

'Haven't got one - none of the students have one.'

'Too expensive for school or students to purchase. Often more confusing to use than the hand-written form.'

'The problem for my dept. & my students is the <u>cost</u> of these calculators!...I cannot even afford enough calculators at $20 each for each student...If someone would provide the calculators for my school, I would love to use them.'

'Dept. decided a class set was lower priority than new textbooks. Our students are not wealthy so no one has bought them.'

'Decile 2 school, students can not afford them.'

'Cost - not a priority for funding in a Decile 4 school'

'I am concentrating on computer usage.'

'We use 'Graphs' software on the computers,....Graphics calculators are too expensive, considering the narrow range of uses they can be put to, compared with computers.'

'Too expensive for class set - would sooner put money into computer software'

'Haven't noticed any real benefit.' (This teacher owned 2 graphics calculators)

'Not necessary - Cost -unavailability (But mainly first reason)'

'No need; no compulsion.'

'lack of confidence in the technology & prefer students to draw without calculator'

'not confident in their use & can't find a reasonable use.'

'cost and lack of training!'

'Financial constraints, lack of confidence.'

'I'm not familiar enough with it.'

'Not user friendly. Computer is easier. Not confident in using them.'

'We have them but don't use them! Mainly because I've never learned how to use one'

'No experience with them - little application seen for math/stats as a result of short course'

'Not enough students have one each; Tests are not geared for use.'

Teachers' Experience and Perception

Teachers' experience and perception of mathematics learning and teaching.

- Years of teaching

Years of teaching mathematics: ________ **(Q_1)**

Distribution of years of teaching of the teachers ranged from a minimum .25 year to a maximum 38 years. It is shown in the following Table 4.6.

Table 4.6

Respondents' Years Experience Teaching Mathematics

Respondents' Experience Teaching Mathematics	Years Reported Grouped in 5-Year Intervals							
Range	0^{+}- 5	6- 10	11- 15	16-20	21-25	26-30	31-35	36-38
Number Responding								

	16	27	41	35	25	17	6	3
(N= 170)	$\bar{x} = 16.6$	$\sigma_n = 8.85$						

From the above table, we can see most of them are experienced mathematics teachers as three quarter of them have been teaching for more than 10 years and at least half has not less than 16 years teaching experience. So they must know clearly what mathematics they should teach at Form 6 or 7 level.

- Level of Teaching

Teaching class: *year 12*____ *year 13*____ (Q_2)

173 teachers answered this question and the distribution according to teaching classes is shown in the following Table 4.7

Table 4.7

Level of Mathematics Class Taught by Respondents

Level of Mathematics Class Taught by Respondents	Class		
	Year 12 Only	Year 13 Only	Year 12 & Year 13

Number Responding			
(N=173)	17	29	127

From the above table, we may make an optimal conclusion that there are 156 replies from Form 7 teachers and 144 from Form 6 teachers

.

- Mathematics class per week

Number of mathematics classes per week at (i) year 12___ (ii)year 13__ (Q_3)

This question is a failure because of its ambiguous wording. To complicate matters even further, some schools are running on 6-day cycles. Many showed their answers in number of classes but others with their answers in number of periods. So the answers vary from as small as 1 to as large to as 10. There are some cautious teachers who put down something like *1 class equals 5 periods* or *1 class equals 4 hours per week.*

Nature of learning mathematics.

- Memorizing facts and rules.

Learning mathematics is mostly memorizing a set of facts and rules. (Q_{13})

- Experimental exploration.

Learning mathematics means exploring problems to discover patterns and make generalizations. (Q_{14})

!72 and 171 responses were collected respectively to the above two statements. Collected data were shown in the following Tables 4.8(A).

Table 4.8(A)

Percent Agreement to Statements about Learning Maths

Learning mathematics means	Number Responding	Percent Agreement Per Attitude Level				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
• exploring problems	172	1.7	1.7	7.0	66.9	22.7
• memorizing facts and rules	171	38.0	39.8	11.7	8.2	2.3
Mean Level of Percent Agreement		5.30	10.87	42.33	44.43	9.10

Teachers are said to be *rule-based* when they believe that the main task of learning mathematics is memorizing and knowing of rules. Those who believe that the core of mathematics learning is *exploring problems to discover patterns and make generalizations* are said to be non-rule-based. From above Table 8(A), there is evidence that only a small proportion (less than 10.5%) of the responding teachers are rule-based, and a majority of teachers (89.6%) *non-rule-based.*

When 'strongly agree' was considered as 'agree' and 'strongly disagree' as 'disagree', for the 170 respondents who commented the 2 statements, we have a distribution shown in the following Table 4.8(B).

Table 4.8(B)

Percent Comparison to Statements about Learning Mathematics

		Learning mathematics is mostly memorizing a set of facts and rules (Q_{13}) (N = 170)	
Learning mathematics means		Agree	Disagree
Exploration problems to discover	Agree	8.8	71.7
pattern and to generalize.	Disagree	1.2	1.8
(N = 170)			

From the above table, one can see that a majority (72.9%) of those who responded to both statements held exactly opposite attitudes towards the two statements. Most (90.5%) of these people agreed with statement 14 and about three quarter (73.5%) disagreed statement 13. However, only 10.6% of the respondents held exactly same attitude to both statements with 8.8% agreed and 1.8% disagreed.

Teachers' experience and perception : role and effect of graphics calculators in teaching and learning mathematics.

I believe that graphics calculators are _____ tools in teaching and learning mathematics. (Q_1)

172 comments on how important graphics calculators are as a tool in teaching and learning mathematics were collected and shown in the following Table 4.9.

Table 4.9

Usefulness of Graphic Calculators in Teaching and Learning Mathematics

Usefulness of Graphic Calculators in Teaching and Learning Mathematics	Ranking			
	Necessary	Frequently Useful	Sometimes Useful	Usually Not Necessary
Number Responding (N=171)	4	34	103	30

Most teachers (80%) saw a use for graphics calculators, but only a few saw a major role for them.

- Emphases in experimental exploration

Using a graphics calculator to teach mathematics allows me to emphasize the experimental nature of the subject (**Q**$_{15}$)

156 comments were collected on this item. 9 and 59 respondents strongly agreed or agreed respectively while 15 and 7 respondents strongly disagreed or disagreed accordingly.

- Encourage student learning

The use of graphics calculators encourages student learning. (**Q**$_{19}$)

170 comments were collected on this item. 10 and 84 respondents strongly agreed or agreed respectively while 11 and 5 respondents strongly disagreed or disagreed accordingly.

- Makes teachers more effective

Using graphics calculators makes teachers more effective. (**Q**$_{20}$)

170 comments were collected on this item. 4 respondents strongly agreed and 44 agreed with the statement while 29 disagreed and 15 strongly disagreed. 78 respondents were neutral to this statement.

A combination study of the above three positive statements is showed in the following Table 4.10(A).

Table 4.10(A)

Percent Agreement to Positive Statements about Graphics Calculators

Using a graphics calculator	Number Responding	Percent Agreement Per Attitude Level: Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
• Enables experimental math studies	156	4.2	9.0	45.8	35.5	5.4
• Encourages student learning	170	2.9	6.5	35.3	49.4	5.9
• Makes teachers more effective	170	8.8	17.1	45.9	25.9	2.4
Mean Level of Percent Agreement		5.30	10.87	42.33	44.43	9.10

- Only for check work

Graphics calculators should only be used to check work. **(Q_{21})**

169 comments were collected and analyzed. A majority 88 respondents disagreed and 35 strongly disagreed. Only 2 respondents strongly agreed and 9 agreed. The rest 35 were neutral to the statement.

- Does not enhance student learning or understanding

Using a graphics calculator to teach mathematics does not enhance student learning or understanding of concepts. (Q_{18})

A total of 169 respondents commented on this item. A majority either strongly disagree (23) or disagree (78). Only a few respondents were either agreed (8) or strongly agreed (4). One third of the respondents were neutral to the statement.

- Too complex for students

Students lack the ability to work with a calculator as complex as a graphics calculator. (Q_{22})

A total of 170 respondents commented on this item. A majority either strongly disagree (45) or disagree (70). About one-seventh of all respondents were either agreed (20) or strongly agreed (5).

A combination study of the above three positive statements is showed in the following Table 4.10(B).

Table 4.10(B)

Percent Agreement to Negative Statements about Graphics Calculators

Using a graphics calculator :	Number Responding	Percent Agreement Per AttitudeLevel Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
• Does not enhance learning	169	13.6	46.2	33.1	4.7	2.4
• Should only be used check work	169	20.7	52.1	20.7	5.3	1.2
• Too complex for students	170	26.5	41.2	17.6	11.8	2.9
Mean Level of Percent Agreement		24.70	44.83	20.78	7.50	2.20

- Main advantages of a graphics calculator

  What are the main advantages of a graphics calculator? (Q_{25})

141 teachers made comments on this aspect and several suggestions could come from the same teacher. 42 claimed the advantage of instant feedback or quick checking; 33 thought that its main advantages were saving time and labour in plotting curve,

transforming graphs or tables; 31 stressed the benefit of its exploratory and experimental nature which led to generalization or discovery; 29 pointed out that the visual capability of graphics calculators that allowed students to visual quickly which promoted their visual understanding as its main advantage. A distribution of the number of main advantaged cited by each respondent is shown in Table 4.11(A). Distribution of main advantages cited is shown in Table 4.11(B).

Table 4.11(A)

Number of Main Advantages of Graphics Calculator in Math Learning

	Number of Main Advantages Given					
	0	1	2	3	4	5 or more
Number of Respondents (N= 175)	34	61	62	14	3	1

Table 4.11(B)

Main Advantages of Graphics Calculator in Maths Learning

Main Advantages		
Topics	Number of Respondents (N = 141)	
Save time & labour in plotting curve/easily transform graphs /tables	63	
Visual aid	62	
• Seeing patterns in graphing/ reason for change/seeing functions		39
• visual quickly to enhance understanding and confidence		33
Various abilities of graphics calculators	47	
• Able to display/scroll/zoom graphs of functions and store data or programmes		21
• Able to display or trace multiple graphs and check focusing on a particular point or different scales.		15
• Able to draw accurate curves or graphs of various complex functions.		14
• Able for a wide range of applications		10
Instant feedback / quick checking/quick graphs/reinforcement	46	
Exploring to discover and/ or generalize	45	
Easy to access to vs computer in classrom/easy to carry/size vc pc	11	

Self motivating and interesting tool to students/	8
Others	3

- Main disadvantage of a graphics calculator

  What are the main disadvantages of a graphics calculator? (Q_{26})

140 teachers made comments about the main disadvantages of a graphics calculator and some teachers each made more than one comments. A distribution of the number of main disadvantaged cited by each respondent is shown in Table 4.12(A). Distribution of main disadvantages cited is shown in Table 4.12(B).

Table 4.12(A)

Number of Main Disadvantages of Graphics Calculator in Mathematics Learning

	Number of Main Disadvantages Given					
	0	1	2	3	4	5 or more
Number of Respondents (N= 175)	35	61	51	17	7	3

Table 4.12(B)

Main Disadvantages of Graphics Calculator in Maths Learning

Main Disadvantages Topics	Number of Respondents (N = 143)	
Lack of access	58	
• Cost/Expensive for individuals to buy/ lack budget		48
• Not enough graphics calculators		25
Difficult to use	50	
• Time taken using / teach how to use it/ a very thick manual		29
• Too complex or difficult for student to use to full range of ability		14
• Easy to forget /not user friendly		11
• Hard to control students' use/ different needs & different skill levels/30 stud		5
• Variety of models - difficult to standardise/fast changing		9
• Security problem		4
Reliant and without understanding	38	
• Go straight to the short cut, rather than try to understand the concepts		28
• Not learning adequately the background theory/ rote learning		19
• Reliant –Students don't learn 'how' in this situation		12
Assessment and equity	14	

Lack of expertise/ technical limitations/training for teachers/stud & teacher	11

Impact of Graphics Calculators in Mathematics Curriculum and Assessment.

- Impact on curriculum and mathematics assessments.

  The impact of graphics calculators on mathematics curriculum is **(Q_{11})**

169 respondents commented on this statement. A majority believed the impact was either 'not very significant' (88) or 'not significant' (32). Only 7 respondents said it was 'very significant' and 42 'significant'.

The impact of graphics calculators on mathematics assessment is ....
(Q_{12})

170 surveyed teachers commented on the impact of graphics calculators on mathematics assessment. A majority believed the impact was neither '*very significant*' (69) nor '*significant*'(42). Only 9 respondents believed that it was '*very significant*' and 50 for '*significant*'.

A distribution of the collected data is shown in the following Table 4.13.

Table 4.13

Ranking of Graphics Calculators Impact

	Ranking				
	N	not significant	not very significant	significant	very significant
Impact on Mathematics Curriculum	169	32	88	42	7
Impact on Mathematics Assessment	170	42	69	50	9

- Impact of Bursary Exam on Use of Graphics Calculators.

  My strategy for using graphics calculators in year 13 differs from that in year 12 due to the Bursary Exam. **(Q_{23})**

164 respondents commented on the above statement. A majority (103) showed neutral to the statement and each a very small number (6) were either strongly agree or strongly disagree with the statement. Among the rest, 32 disagreed while 17 agreed. A distribution is shown in the following Table 4.14

Table 4.14

Level of Percent Agreement to the Impact of Bursary Exam on Use of Graphics Calculators

	Percent Agreement Level					
	N	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Bursary Exam affects my Use Graphics Calculators in Year 12 & Year 13	164	3.7	19.5	62.8	10.4	3.7

The majority of 62.8% shown neither agree nor disagree makes this finding unable to derive any definite answer

- Uses of graphics calculators in Curriculum.

  In which parts of the curriculum are graphics calculators most helpful? (Q_{24})

To this open-end questions, 142 replied were collected and analyzed. Each reply may contains several suggestions. The data collected covers a wide range of mathematics. 78 suggestions are related to graphing; 45 related to statistics; 43 stated equations; 39 related to topics in calculus; 34 related to functions and transformations; 29 about trigonometry; 23 in geometry; 13 in pattern and modeling and 8 in algebraic solving.

However, there are also 6 teachers replied either they did not know or they had no experiment to make any comment.

Distributions of the number and topic of uses suggested by each respondent are shown in the following Tables 4.15(A) and 4.15(B).

Table 4.15(A)

Number of Uses in Curriculum

	Number of Uses Given					
	0 uses	1 use	2 uses	3 uses	4 uses	5 or more uses
Number of Respondents (N= 175)	32	37	46	30	24	6

Table 4.15(B)

Usefulness of Graphics Calculators in Mathematics Curriculum

Uses of Graphics Calculators in Curriculum Topics	Number of Respondents (N = 143)
Graphing	78
Statistics	45
Equations	43
Calculus	39
Function/transformation	34
Trigonometry	29
Geometry	23
Pattern & Modeling	13
Algebraic Solving	8

Training and Public Support in Using Graphics Calculators

Types of training received.

Have you ever been trained in the use of graphics calculators? *Yes __* *No __*

If yes, how? *(i) short course* *(ii) demonstration*

(iii) conference workshop *(iv) self-instruction* (Q_4)

173 teacher answered the above question and 117 said they have received at least one of the four kinds of training mentioned in the questionnaire. Data collected is analyzed and shown below in Table 4.16.

Table 4.16

Types of Training Received

Training in Use of Graphic Calculators (N= 173)	Number of Respondents
No Training	56
Training	117
Short Course	73
Demonstration	37
Conference Workshop	34
Self-Instruction	60

7 teachers said they had taken part in all of the first three types of training and there were 99 teachers who had taken part in at least one of these three types of training.

Confidence and skills in using graphics calculators.

I lack confidence and skill with graphics calculators (Q_{16})

171 respondents commented the above statement. Distribution of their feedback is shown below in Table 4.17.

Table 4.17

Confidence and skills in using graphics calculators

	N	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		Agreement Level				
I lack confidence and skill with graphics calculators	171	19	46	34	42	30

From the above table, about 38% of the responding teachers had confidence in using graphics calculators while about 42% did not have confidence or skills for this technology.

Priority of graphics calculators in mathematics department.

Teaching with a graphics calculator is a high priority in my department. **(Q_{17})**

170 respondents commented the above statement. Distribution of their comments is shown below in Table 4.18.

Table 4.18

Priority Rating of Graphics Calculators

	N	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		Agreement Level				
It is a high priority to teach						

mathematics with graphics calculators	170	53	64	33	16	4

From the above table, it is obvious that only about 12% of teachers agreed that a graphics calculator had a high priority in their teaching mathematics while a majority (about 69%) disagreed

Community support in use graphics calculators.

What kind of assistance can mathematics teachers currently get in the use of graphics calculators? Is this enough? **(Q_{27})**

Analyzing the feedback to question 27 led to the following: 145 teachers made comments to this question among which 36 claimed they could find helpful source books or promoting courses in business sectors; 58 said there were courses or workshops run by either local College of Education or Math Associations; 4 teachers pointed out that one could get help from mathematics advisors or facilitators while 14 claimed that they had peer support. Finding is summarized in the following Table 14.9.

Table 4.19

Community Support for Use of Graphics Calculators

Support		Number
Business sector		
	Source books	13
	Promoting course	26
Mathematics Association or College of Education		
	Short course/workshop/conference	50
	In-service Course	10
Individual help		
	Advisory/facilitator	4
	Peer support	14

Categorical Study

This section aimed to find out if there were any characteristics for a particular category of respondents. The answers of questions 7 – 23 of each category were compared in order to find any categorical characteristic that may exist. All neutral answers in Likert-scale questions were excluded in order to make their answers compatible with those of multiple choice type questions. Five categories of respondents were selected. Those who declared that they have received any of the four type of training and those who denied form the two categories *Trained* and *Not-trained.* Those who agreed with question 13 and those who agreed with question 14 form respectively categories *Rule-based* and *Not-rule-based. Total* represent all respondents with a definite answer to at least one of the questions 7-23. Since the answer to each question can now be divided into two types, those whose answer favoured one of the first two options are called type A answer and the rest type B. The ratio of type A answers for each question in a category is compared with that of the same question in another category with opposite meanings. Two such comparisons were done. In the first case, percent agreement to each question, (i.e. the ratio of type A answers of each question) among the three categories *Total, Trained* and *Not-trained* were compared. In the second case, the percent agreement of each question of the three categories *Total*, *Rule-based* and *Non-rule-based* are compared. Result of the two comparisons were shown below in graphs 4.3 and 4.4.

In figure 4.3, the category *Trained* has the highest percent agreement to each of the positive statement of graphics calculators and the lowest percent agreement to each the negative statements and vice versa for the category *Not-trained.*

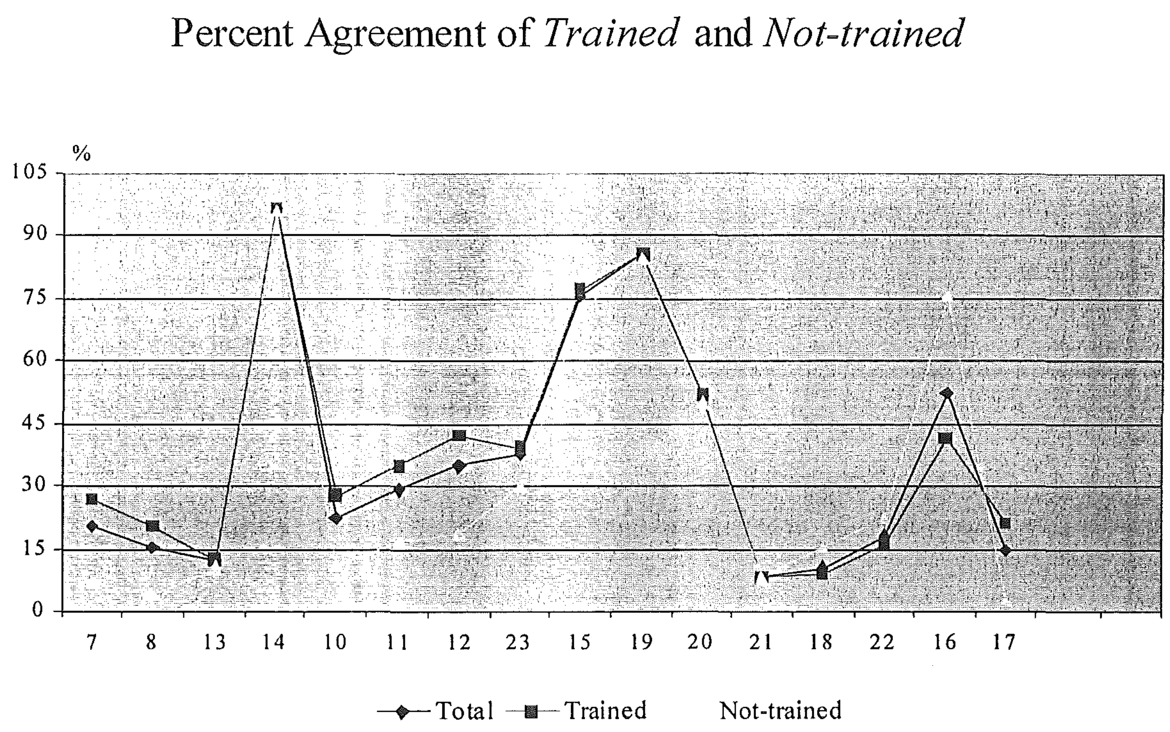

Figure 4.3

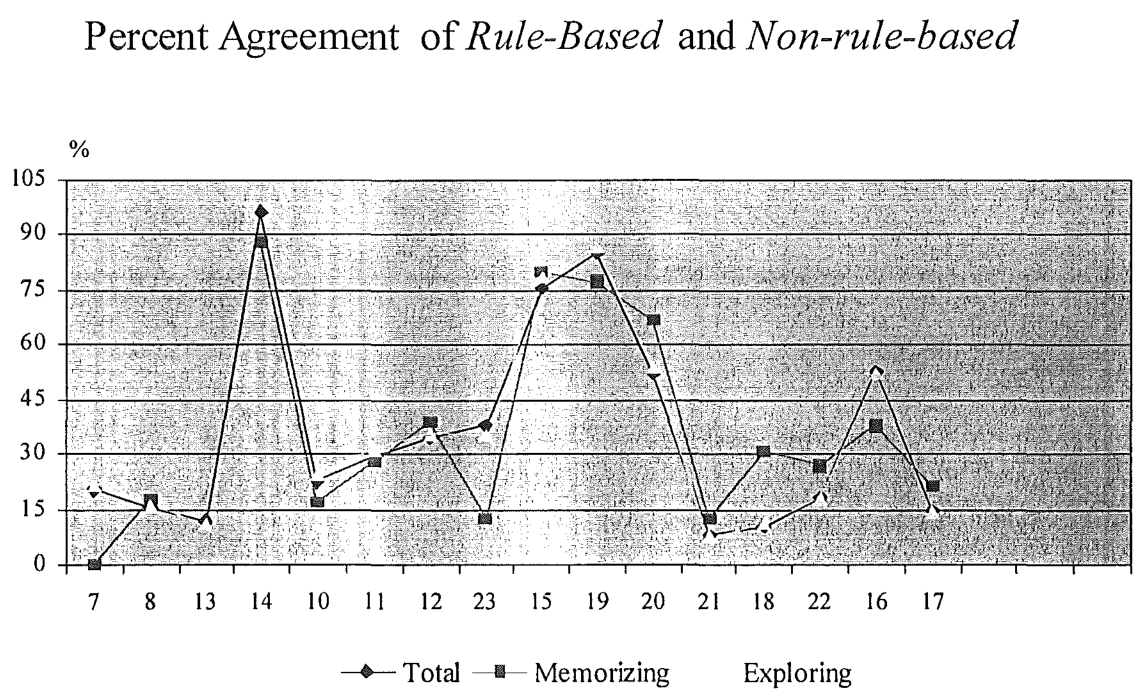

Figure 4.4

Summary

The aim of this study is to find out the role and effect of graphics calculators in secondary mathematics education as perceived by senior form mathematics teachers in New Zealand.

A survey to all New Zealand high schools was conducted in mid-April 1999. Data was collected throughout a questionnaire which was designed based on the researcher's long term teaching experience in Hong Kong and a review of some recent research articles (Drijvers & Doorman, 1996; Penglase & Arnold, 1996; Scott & Jackman, Ballantine, & Harvey 1999; Fleener, 1995; Simonsen & Dick 1997, Simmt 1997; Tharp, Fitzsimmons & Ayers, 1997) in this field. A letter, each containing two copies of the same questionnaire, was sent to each of the 243 high schools in mid-April 1999.

The two questionnaires for each school were originally intended to be filled in by one Form 6 and one Form 7 mathematics teacher. But among the 175 replies, 127 were from teachers teaching both Form 6 and Form 7; 29 and 17 respectively from those who were only teaching Form 7 or Form 6. Besides, two blank questionnaires, together with an explaining letter, were returned from a school in Auckland. Among the schools with returning questionnaires, one school in Auckland did return 12 questionnaires; two other schools, one in Auckland and another one in Ashburton, did each returned 5 and another 10 schools did each returned 2 questionnaires. The rest 133 questionnaires were returned individually.

Geographical origins of 97% (170) of the total replies can be identified either by addresses supplied or by recognizable postal seals. Among the identified questionnaires, 72% (123) came from North Island while 28% (47) from South Island. 25% (43) of the identified replies came from Auckland; 17% (29) from Wellington; 14% (24) each from Christchurch and Waikato; 6% (11) from Napier; 4% (7) from Nelson; about 4% (6) each from Dunedin and Gisborne; 3% (5) each from Invercargill, Wanganui, Ashburton and less than 1% (1) from Whangarei.

Most respondents are experienced teachers. 170 (97% of the total replied) teachers reported that they had been teaching a time ranging from a minimum .25 year to a maximum 38 years. Just a little less than 10% of them had not more than 5 years teaching experience while 75% had a teaching experience for more than 10 years. Their mean years of teaching is 16.6 years.

173 (99% of the total replied) teachers told which Form they were teaching for the current year. 73% (127) of them were teaching both Form 6 and Form 7; 17% (29) teachers were teaching Form 7 only and the rest 10% (17) teachers were teaching Form 6 only. It would be an optimal conclusion that there were 156 replies from Form 7 teachers and 144 from Form 6 teachers.

65 (37% of the total replied) teachers said that they did own one or more graphics calculators and 107 (61% of the total replied) said they didn't. 63 teachers filled in the names of their graphic calculators. One teacher owned 3 graphics calculators while another one owned 2. The most popular of these teachers' graphics calculators are products of Casio (50) and seconded by that of Texas Instrument (11). Only a few teachers owned products of HP (3) and Sharp (2). 54 (31% of the total replied)

teachers mentioned how long they had used them. Their experiences in using their own graphics calculators range from 1 to 10 years and with a mean 2.9 years.

As for students, 73 (43% of those who commented) teachers replied that only some of their students own their graphics calculators while 97 (nearly 57%) replied that none of their students did have a graphics calculator.

81 (46% of the total replied) teachers replied that they did use graphics calculators at school while only 76 (43% of the total replied) stated that they had experiences ranging from 0.1 year to 8 years together with a mean 2.2 years. Products of Casio and IT are still the two most popular graphics calculators used in schools.

About half (84) of the total respondents said that they had never used graphics calculators and only one said that he/she had always used graphics calculators. Those who did use, either sometimes or when needed, formed the other half of the sample.

For students, it is reported by 172 (98% of the total replied) teachers that only in 10% (17) of their senior classes do all the students have a graphics calculator while in just under half (80) of the senior classes, no students have graphic calculators.

94 (54% of the total replied) teachers said they did not use graphics calculators at school and 71 (41% of the total replied) explained. They gave 4 main reasons: 54% (38) stated the unavailability of graphics calculators due to either cost or low priority ; 30% (21) used or preferred to use PC instead of graphics calculators; 15% (11) didn't use graphics calculators either because they thought that was not important or because they found no real benefit from using them; 14% (10) said they didn't have confidence in using this technology.

It seems that most teachers are liberal and non-ruled-based. Among the 170 teachers who responded, nearly all (98.4%) of these people agreed with statement that 'learning math's means exploring problems to discover patterns and make generalizations.' and a majority (78%) disagreed with the statement 'learning mathematics is mostly memorizing a set of facts and rules.'. A majority (72.9%) held exactly opposite attitudes towards the two statements.

Most teachers (82%) see some uses of graphics calculators, but only a few see a major role of them. A majority (73%) thought that graphics calculators could serve other uses other than mere a 'work checker'.

More than half the teachers believed that the use of graphics calculators both encouraged (55.5%) and enhanced (60%) student learning or understanding of mathematical concepts. About 40% of the teachers believed that the use of a graphics calculator allowed them to emphasize the experimental nature of mathematics. However, teachers were diverse when considering whether the use of graphics calculators could make their teaching more effective.

From the responses of 142 teachers, a teacher could make various suggestions and no definite conclusion could be drawn about the main advantages of use graphics calculators in secondary mathematics education. However, some main advantages were believed to be instant feedback or quick checking (30%), experimental exploration and simulation (28%), save time and labour in plotting/transforming curve (23%), visual display and visual understanding (22%), seeing patterns in graphing or functions (20%), abilities to display accurate curve/scroll/zoom/store programme (14%), easier to access than a personal computer in terms of size and price (8%).

Teachers' perceptions concerning what the main disadvantages of use graphics calculators were diverged, just as their perceptions concerning the main advantages of these tools. Among the 143 respondents, some main disadvantages believed by some teachers were complex and difficult to use (35%), high cost or lack of budget (34%), time consuming for learning/teaching how to use (20%), go straight to the short cut rather than try to understand the concepts (29%), problem of availability or not enough for students to bring home (9%), reliant ---- student don't learn 'how' to solve (8%), lack of expertise or training for teacher or student (8%).

A majority (77%) believed the impact of graphics calculators on curriculum was fairly *'significant'*. However, for 142 teachers, over half (55%) believed that graphics calculators would be most useful in topics about graphing, about 30% each in topics about statistics, and solving equations, about 27% in topics about calculus and 20% in topics about trigonometry.

A majority (66%) believed that the impact of graphics calculators on assessment was scarcely significant. No definite conclusion about how the Bursary exam affects teachers' strategies could be drawn because the majority (62%) showed no idea to it.

117 (67% of the total replied) did tell which of the four kinds of training to use graphics calculators they had taken part and some teachers said they had attended different kinds of training. 42% (73) of them attended short course; 21% (37) saw demonstration; 20% (34) attended conference workshop and 35% (60) learnt from self-instruction.

Regarding to community support, among the 126 teachers who made their comments, 29% said they could find helpful source books or promoting courses run by business sector; about half (46%) said there were courses or workshops run by either local College of Education or Math Associations and 11% said that they had peer support. The majority of responses did not state clearly whether the community support was enough or not. However, a little more than one-third (39%) of the teachers thought the community support was not enough while 11% said that community support was enough. In fact, 117 teachers (about 69% of those who commented) said that 'teaching with a graphics calculator' is not a high priority in their math's department. 72 teachers (42% of those commented) said that didn't have confidence or skill for this technology.

Chapter 5

Discussion, Implications and Conclusions

Discussion

Graphics calculator technology has been available for some time since the invention of the first so called graphics calculator by Casio in 1985. Over the past ten years there has been considerable research on the effects of graphing calculator use in mathematics education. These studies have most often addressed the effects on student performance and changes in the ways how teachers teach mathematics. Little research has been done on teacher knowledge and beliefs about graphics calculator use and the derivative practices in the mathematics classroom. As the classroom teacher is the critical agent with respect to change in education, identifying this knowledge and these beliefs and practices is a crucial step in reforms based on technology. With the increasing sophistication of hand-held computing technology, these issues become even more critical.

Accessibility.

Research on the *accessibility* of graphics calculators in daily teaching or learning high school mathematics is still new enough that relatively little research has found its way into the journal literature. Conference proceedings--in particular, the Annual International Conference on Technology in Collegiate/ High School Mathematics--and doctoral dissertations are the most fruitful sources of research on graphing calculators at this time. In United States, the *Curriculum and Evaluation Standards for School Mathematics* (NCTM 1989) made the following underlying assumption for grades 9-12 (p.124):

> *"Scientific calculators with graphing capabilities will be available to all students at all times."*

Dunham & Dick (1994)[v] stated that The National Council of Teachers of Mathematics has long advocated the use of calculators including graphics calculators at all levels of mathematics instruction and they commented:

> "*Commenting on changes in undergraduate mathematics education for the Mathematical Association of America, Leitzel (1993) noted the "explosive growth in the use of graphing calculators in secondary schools" and urged college mathematics faculty to take advantage of students' facility with this technology.*"
>
> [P.1[vi]]

Kissane [1995] has pointed out that *the key to understanding the significance of graphics calculators is their potential for increasing the accessibility of technology to individual students.* There are two aspects to this accessibility. First, the purchase price of graphics calculators, while still too high for many individual students in many countries, goes down rapidly and places them within reach of many more classrooms than microcomputers do. Since graphics calculators come complete with their own mathematical software, while computers demand that the software be purchased separately, a school can purchase a class set of graphics calculators for around the same price as a single microcomputer sufficiently powerful to operate modern innovative software when the cost of the software is taken into account. The remarkable flow in recent sales of graphics calculators in affluent western countries suggests that many schools and individuals find them affordable.

The second aspect of accessibility is a consequence of the physical size of graphics calculators. Small, light, battery-operated computers are clearly much more portable than are large, heavy, electrically-powered computers. Graphics calculators are light and small and battery-operated. They can easily be put into pockets and accompany students to an examination room or on a field trip. This mobility of graphics calculators and their increasing power make them the most significant technology tool and 'intelligent partner' of mathematics education. Bert K. Waits and Franklin Demana (1992, 1996)[vii] explained that these inexpensive graphics calculators were really computers with built-in graphing software and could be viewed *as computers available to all students* because of their low cost, ease of use, and portability. They and some other people like Cathy Seeley and Charles Dana called modern graphics calculators *hand-held computers.*[viii] They viewed graphics calculators as necessary tools for equity in mathematics. Waits & Demana (1996) argued that only a few elite would benefit if teachers had to rely exclusively on expensive computer laboratories to deliver computer enhanced visualization in mathematics teaching and learning. Seeley & Dana (1995) claimed that the overriding responsibility (of an education system) is to ensure that these technological tools are used equitably for all students. They argued that if we want more students to succeed in high level mathematics, we must therefore change what and how we teach it and hand-held technology is critical to make the necessary changes. They commented:

> *"These tools now perform most of the mathematical procedures that have typically comprised the school mathematics curriculum, including calculating with whole numbers/decimals/fractions, graphing equations and inequalities, solving equations, factoring polynomials, and constructing and manipulating geometric figures, just to name a few highlights. Some of these computers sport dynamic color displays, movable cursors, computer-style keyboards, cable links to scientific experimental probes and desktop computers, and connections to printers. These represent just some of the capabilities of hand-held computers at the time of this writing in 1995; future advances lie only in our imaginations and in science fiction, perhaps even beyond.*
>
> *Technology such as that described above is absolutely necessary in order to move mathematics teaching and learning in the directions described in the National Council of Teachers of Mathematics standards and other descriptions and guidelines about the reform of school mathematics (see References)."*
>
> *[pp.2-3]*

But it seems that the availability of graphics calculators to every secondary school student, as assumed by the Curriculum and Evaluation Standards for School mathematics (NCTM, 1989) and urged by those researchers mentioned above, is still a dream in typical high schools in any county. In United States, the place where the largest quantity of graphics calculators has been used at high school level, Donald (1998) investigated the availability and distribution of calculators and computers for the mathematics classes in public high schools across the State of Virginia. The study surveyed the mathematics department heads from 80 public high schools from school divisions located throughout the State of Virginia through the use of a self-administered mail questionnaire. Results from this study indicate that: (1) without the financial support from the State of Virginia, sufficient numbers of graphics calculators and computers would not be available at these schools; (2) without a mandate from the State in the form of Standards of Learning for Virginia Public Schools, many teachers would not be using graphics calculators in the classroom. Milou (1998) investigated secondary mathematics teachers use of, and attitude towards, the graphing calculator. Results of the study showed that only 36.2% of the schools provided graphing calculators for students and teachers of algebra I were using graphing calculators to a significantly lesser degree than teachers of algebra II.

In this study, only 38% of the respondents has their own graphics calculators and 49% said that they had never used the technology in their mathematics classes. From the observation of the respondents, one could easily derived that the majority of the Year 12 and Year 13 students did not own any graphics calculators. About 10% of the respondents reported that all their students used graphics calculators in mathematics class and 5% reported that most of their students used graphics calculators in mathematics class. The report from 47% of the respondents showed none of their students used this technology in mathematics class. 38% of the respondents said only some of their students used graphics calculators in mathematics class. From the above data, one could conclude that a majority of the New Zealand high schools could not supply enough graphics calculators for their Year 12 or Year 13 students. This study confirmed with the findings of Donald (1998) and Milou (1998) that *cost was a major factor* (54% of those respondents who did not use this technology in class) *in the non-use of graphics calculators*. Besides, teachers' preference, experience and confidence with using the technology were the second, third and fourth factors that kept them off using graphics calculators. 30% said they used or preferred PC instead of graphics calculators; 15% said they did not find any real benefit using graphics calculators while 14% said they have no confidence using them. This in turned affected their students' accessibility to the technology.

Seeley and Dana (1995) pointed out that *schools have* a responsibility to provide every student with access to appropriate (hand-held computer) *technology* and they commented:

> *Technology such as* (graphics calculators) *is absolutely necessary in order to move mathematics teaching and learning in the directions described in the National Council of Teachers of Mathematics standards and …Unfortunately, many efforts to infuse* (the) *technology into schools have either ignored calculators and hand-held computers or have greatly underestimated the need for these tools to be in the hands of every students all the time.* (P.3)

It seems that this study has shown that "the need for graphics calculators to be held in the hands of every students all the time" has been ignored by a number of schools and some math teachers. A majority (78%) of the respondents did not think the technology an important tool to be used frequently in teaching and learning mathematics. For some of them, the "individual and frequent accessibility" of the technology has been outweighed by the more powerful but less accessible PC's. It is true that many mathematics teachers, especially for those who have taught high school mathematics for more than 15 years (51% of the respondents), have had hand-on experience on a desktop or PC before the appearance of the graphics calculators. For these teachers, their experience using desktops or PC's equipped with suitable software could easily convinced them the superiority of a desktop or PC as compared with graphics calculators. They pointed out that the display of a desktop was more attractive, in terms of colour, size and accurate scale and capable for a wider range of application when compared with a graphics calculator. This finding seems to agree with those in Kissane (1995b, p.3), Penglase and Arnold (1996 p.84). Fleener's (1995, p.496) study showed that teachers may respond differently to (graphics) calculator experience because of some combination of prior experience and philosophical orientation. About two third of the respondents did not have their own graphics calculators and half of them said they had never use this technology in school or class. Their third and four reasons for their not using the technology are 'cannot find real benefits in graphics calculators' and 'lack of confidence or training'. Penglase and Arnold (1996) reported both positive and negative aspects of graphics calculators and commented:

> "*It is still unclear, however, whether the graphics calculator is an effective tool for developing understanding of transformation of functions and graphs…Also we need to ask whether the shift in emphasis from algebraic manipulation and proof to graphical investigation, which tends to occur with the use of graphics calculators (Army, 1992), is desirable..*" (p. 82)

> "*Teachers and students who know little or nothing of the graphics calculator will most likely be reluctant to use them, and certainly will not be able to utilize their full potential.*" (p.85)

Hubbard (1998) showed that lack of students' "hand-on" time with graphics calculators may account for an incomplete understanding of its capabilities. The study also showed that other possible causes including a lack of both instructional materials and in-service training related to the graphics calculator technology. Only 38% of the respondents had confidence, while 42% did not have confidence and the rest 34 made neutral comment for not using the technology. This may be resulted from the low priority of graphics calculators and the limited financial budget in the Mathematics Department of many schools. Not enough in-service training course prevented some teachers from being competent in this technology.

<u>Nature of math and role of graphics calculators.</u>

Teachers who believe that, learning mathematics means mainly memorizing a set of facts and rules, are usually labeled as 'rule-based' teachers and those believe that, learning mathematics means exploring problems to discover pattern and make generalization, 'non-rule-based'. Research showed that 'rule-based' and 'non-rule-based teachers differed may respond differently to this technology. Tharp, Fitzsimmons & Ayers (1997, p.558) showed that there was a high correlation between teachers' views of mathematics and teachers' views of the use of calculator. Their findings indicate that teachers who hold a more rule-based view of math are more likely also to hold the view that the technology do not enhance instruction and may even hinder it. This study showed that nearly all respondents are 'non-rule-based and only a small portion about 10% are rule-based. However, this study found that most rule-based respondents agreed that learning mathematics also meant exploring problems to discover pattern and make generalization but the non-rule-based were most probably against the idea that learning math was mostly memorizing facts and rules.

Advantages and disadvantages to use graphics calculators.

There was no major advantage recognized and agreed by the majority of all respondents. However, there were some advantages, each recognized and agreed by a small part of the respondents with percent agreements range from 45% to 32%. They are (1) Save time and labour plotting or modifying graphs or tables (45%); (2) Visual aid to seeing patterns which enhance understanding and confidence (44%); (3) Powerful tool that can draw accurate graphs, perform tasks like multiple displays, zoom, trace, etc. (33%); (4) Instant feedback, quick checking to reinforce (33%) and (5) Exploring to discover and/or generalize (32%). The teachers perceptions of the advantages of graphics calculator use appeared to be instructionally related, demonstrating concern for the learning environment of the students and teacher. Many of the perceived advantages are similar to those cited by earlier researchers reported in (Simonsen & Dick, 1997; Penglase & Arnold Apr. 1996): time and labour to plot or to modify a graph or a table are saved; visualization skills are enhanced (Drijvers, Paul; Doorman, Michiel, Dec 1996, Dunham & Dick, 1994); understanding and confidence are enhanced through instant feedback and experimental exploring (Ruthven, 1990; Drijvers, Paul; Doorman, Michiel, Dec 1996; Hollar & Norwood, Mar 1999). Only 8% respondents mentioned, as a main advantage of this technology, the superiority of graphics calculators to PC on both size and easy to access in classroom. This finding could explain why the concept of 'individual and frequent accessing' to graphics calculators seemed to be ignored by most of the respondents. The fact that 6% of the respondents believed that 'self motivating and interest tool to students' as a main advantage of graphics calculators might reflect the small portion rule-based respondents.

Just as that for the main advantage of graphics calculators discussed above, there wase also no major disadvantage recognized and agreed by the majority of all respondents. However, some findings reported in Simonsen & Dick, (1997, pp.249-252) was found at minor trend in this study. Lack of access was recognized by 41% indirectly of the respondents as a main disadvantage of use graphics calculators – 34% claimed the technology was too expensive and they lacked budget; 17% just said there was not enough graphics calculators available to their students. The second main disadvantage found related to difficulties in graphical calculator use (35%). 20% of the respondents claimed that the time taken in using or teaching students how to use graphics calculator was a main disadvantage, about 10% pointed out that students being unable to use to a full range of ability of the technology was one of its main disadvantage. Calculator reliant without understanding was the third main disadvantage cited by 27% of the respondents. Equity to assessment and the lack of technical support was also reported respectively by about 10% and 8% of the respondents as main disadvantages of graphics calculators. Bradley , Kissane & Kemp (1996, p.4) pointed out the problems related to access and equity could not be resolved completely, but with the steady reduction in price, more students could afford their own graphics calculators, rather than having to rely on borrowing one. Although the wide range of capabilities of graphics calculators has caused concern in terms of equity, most work at secondary level is done at the lower end of this technology where differences are less important and less sophisticated calculators can be programmed to ensure that students are not disadvantaged. They also pointed out that many concerns about calculator dependency expressed by secondary mathematics teachers were essentially concerns about arithmetic operations and the mathematical stakes were raised somewhat in the case of graphics calculator, since much more than mere arithmetical calculation was involved (p.3). Teaching students how to make good choices may well reduce their dependency on the calculators. The appropriateness of the use of this technology in different contexts varies considerably and students should be encouraged to build up an awareness of the need to think about that appropriateness before reaching for their graphics calculators.

<u>Impact of graphics calculators in mathematics curriculum and assessment</u>

The majority did not agree with a significant impact of graphics calculators on mathematics curriculum. However, graphics calculators are considered useful in curriculum topics related to graphing (54%), statistics (31%); equations (30%), calculus (27%), function and transformation (24%). There appears to be general agreement among researches that students' understanding of graphing concepts is markedly enhanced by the use of graphics calculators (Penglase & Arnold 1996 pp.69-72).

However, research dealing with the impact of the graphics calculator on learning regarding function leads to mixed conclusion. Devantier (1993) and Alexander (1993) reported some positive results in regard to graphics use in this area but Rich (1991) failed to find a strong relationship between graphics calculator use and the development of conceptual knowledge of functions. Chandler (1993), who had conducted a short study on transformation of functions with graphics calculators at a US high school, concluded that graphics visualisation of concepts and problems contributed to an increase in students understanding and achievement in the area. Penglase & Arnold (1996 p. 68) pointed out that the inconsistency in the result s were as likely to be derived from the differences in instructional approaches and assessment procedures as from the use of the calculators themselves.

This study found no major agreement to a significant impact of the technology on mathematics assessment. Since the majority commented neutrally to whether was a respondent's strategy of using graphics calculator affected by the Busary examination, there is no decisive answer to this question. Clearly, the level of availability of graphics calculators to all participating students is critical to involve this technology in assessment especially public examinations. The banning of TI92 in the 1998 Bursary examination of New Zealand seemed to reflect a local concern to equity of graphics calculator use in assessment.

Conclusion

Findings.

This is a descriptive study of the experiences and perceptions of senior secondary school teachers in regards to the role of graphics calculators use in secondary mathematics education. The *first* and most important finding in this study is that only a small portion of both teachers and students have accessed to the technology in class and the cost of graphics calculator is, as mentioned in some recent studies, the main barrier to their accessing to this technology. It seems that this study has, to some degree, confirmed the finding of Simmt (1997) that the beliefs, attitudes, and conceptions of mathematics and mathematical education which contributed to the teachers' philosophies were manifested in the sum of their experiences in class with students. Some teachers refused to use this technology and replaced it by using PC software(s) even when they have a class set at hand.

The *second* finding is that most respondents agreed that learning mathematics means exploring problems to discover patterns and make generalization and only a very small part of the respondents agreed that learning mathematics means mainly memorizing a set of facts and rules. If they are labeled respectively *rule-based* and *non-rule-based*, a generalization could be that most New Zealand Year 12 and Year 13 mathematics teachers seem to be *non-rule-based.*

The *third* finding is that the trained and not-trained respondents showed opposite attitude to the role of graphics calculators in secondary mathematics education: the trained ones have always had a higher percent of positive agreement to every descriptive statement about the role of this technology in secondary mathematics education. This seems to suggest that enough training for every mathematics teacher is essential for integrating this technology into secondary mathematics education.

One interesting finding in this study is that most *rule-based* teachers tended to accept the idea of *non-rule-based* while most *non-rule-based* tends to repel the idea of the *rule-based.* This seems to contradict the fact that the *rule-based* is generally recognized to be more conservative than the *non-rule-based.* One explanation to this finding could be the serious influence of educational constructivism in contemporary mathematics education of New Zealand (Mathews, M.R., Ed. 1998 p.1). Teachers who firmly uphold this philosophy, especially that developed by Von Glasersfeld, tend to repel the role of memorizing in any learning situation. Further study is needed to justify this guess.

Limitations.

On one hand, although most findings in this study could be found in previous research studies, credibility of many findings, such as what the main advantages or disadvantages of graphics calculator use are, may be hindered by being all minor trend (i.e. confirmed by less than 50%of the respondents) answers. The lacking of practical experience of a majority of the respondents in this study may even supply a distorted picture of the role of graphics calculators in secondary mathematics education. On the other hand, the generalizations of these findings is limited by the methodology used. Firstly, the use of volunteers directly limits the generalization of results and conclusions. Secondly, though the results appeared to reveal internal consistency of teachers' responses, data which were collected through questionnaires without any justification obstructed the credibility of the conclusions. It would be safe to say that findings reported in this study represent only the self-reported experiences or perceptions of the teachers surveyed. However, due to the large sample size (N = 175) and the geographical distribution of returned questionnaires, a few cautious generalizations could be drawn without much danger.

Further research.

Some findings need to be justified in further research. A deeper study is needed to distinguish the *rule-based* and the *non-rule-based* in order to clarify why the *non-rule-based* New Zealand high school mathematics teachers tend to reject the 'memorizing' nature of mathematics learning. Most mathematics teachers do agree with the 'construct' ability of their students. Yet also a large number of them, especially experienced Asian teachers, do recognize the benefit of standing on the shoulder of giants and agree with the importance of 'memorizing a set of facts and rules'. Besides, further research with proper sample are needed, either to justify the findings in this study concerning what are the main advantages or disadvantages of graphics calculator use, or to clarify the impact of public assessment such as the Bursary examination on teachers' strategy of using graphics calculators.

End

[i] Original message from Vince Geiger to AAAMT@eddirect.com and quoted in the email from A. Lawrence < A.Lawrence@massey.ac.nz> to Tony Sears <eureka@sinesurf.co.nz>, 8, Nov. 1998, 11:20

[ii] Original message from Marjorie Smith to AAMT@listserver.eddirect and quoted in the email from A. Lawrence < A.Lawrence@massey.ac.nz> to Tony Sears <eureka@sinesurf.co.nz>, 8, Nov. 1998, 11:20

[iii] Original message from David Leigh-Lancaster to from A. Lawrence < A.Lawrence@massey.ac.nz> on 4 Nov 1998, 13:56

[iv] Research compiled by Heidi Pomerantz, under the direction of Bert Waits, for (USI/CPMSA) Forum, Dallas, Texas on 4 Dec 1997. <http://www.ti.com/calc/docs/therole.htm>

[v] Dunham, P. H. & Dick, T. P. (1994). Research on graphing calculators. *Mathematics Teacher, 87*(6),440-445.

[vi] Reprinted with permission from *The Mathematics Teacher,* copyright September, 1994 by the National Council of Teachers of Mathematics [website Updated 10/19/98]

[vii] Bert K. Waits and Franklin Demana, 1996, *A Computer for all Students - Revisited*
Copyright December 1996 by the National Council of Teachers of Mathematics.[This document contains portions of an unedited version of an article to be published in the Mathematics Teacher.] contact Bert Waits at waitsb@math.ohio-state.edu for the whole article.

[viii] See Cathy Seeley, July 1995, *Technology and Equity in Mathematics* ,University of Texas at Austin. http://www.tenet.edu/tcks/math/resources/techaccess.html